

Exhibit 7

UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF NEW YORK

ALASKA ELECTRICAL PENSION FUND, et al.,

Plaintiffs,

--v--

BANK OF AMERICA CORP., et al.,

Defendants.

Civil Action No. 14-cv-7126 (JMF)

EXPERT REPORT OF PROFESSOR PAUL MILGROM

HIGHLY CONFIDENTIAL
SUBJECT TO PROTECTIVE ORDER

January 22, 2018

TABLE OF CONTENTS

I.	Assignment.....	1
II.	Background and Qualifications	2
III.	Dr. Pirrong Accurately Summarizes the Market Microstructure Literature Regarding the Permanent Price Impact of Potentially Informed Manipulative Trades	3
IV.	Dr. Glosten Fails to Establish His Claim That the Price Impact of Manipulative Trades Is Only Temporary	7
	A. Manipulative Trades Should be Viewed as <i>Potentially</i> Informed, Not as “Uninformed” ..	7
	B. Potentially Informed Manipulative Trades Result in Permanent Price Impacts	10
V.	Conclusion	18

1. I submit this report in support of Plaintiffs' motion for class certification. The scope of my engagement and my qualifications are set forth below. By way of background, together with one of the Defendants' experts, Professor Lawrence R. Glosten, I am the co-author of a paper that both Dr. Glosten and Dr. Craig Pirrong, one of the Plaintiffs' experts, have cited: "Bid, Ask and Transactions Prices in a Specialist Market with Heterogeneously Informed Traders," *Journal of Financial Economics* 14, no.1 (1985): 71–100.

2. As I detail below, Dr. Pirrong's interpretation that potentially informed manipulative trades can have a permanent price impact accords with the analysis that Dr. Glosten and I put forward in that paper. By contrast, Dr. Glosten's critiques that manipulative trades have no permanent price impact are not supported by the market microstructure literature.

I. Assignment

3. Plaintiffs' counsel have asked me to opine on two issues:

(1) *First*, whether Dr. Pirrong accurately interpreted the market microstructure literature regarding the price impact from potentially informed manipulative trades.

(2) *Second*, whether Dr. Glosten's claim that there is no permanent price impact from manipulative trades is overstated.

4. Based on my expertise in the area of market microstructure, including the effects of trading activity and information on price, as well as my expertise in a wide range of fields of economics, I am of the opinion that:

(1) Dr. Pirrong's report fairly and accurately characterizes the market microstructure literature and the principles it teaches; and

(2) Dr. Glosten's assertion that there is no permanent impact from manipulative trades is unsound, as it is often based on a misinterpretation or mischaracterization of the relevant market microstructure literature.

5. The balance of my report is organized as follows:

Section II provides an overview of my background and qualifications, including in the area of market microstructure.

Section III contrasts Dr. Pirrong's and Dr. Glosten's stated understandings and interpretations of the market microstructure literature.

Section IV discusses Dr. Glosten's critiques concerning the temporary nature of price impact from manipulative trades.

Section V provides concluding remarks.

II. Background and Qualifications

6. I am the Shirley R. and Leonard W. Ely Jr. Professor of Humanities and Sciences, School of Humanities and Sciences, as well as Professor, by courtesy, of Management Science and Engineering, School of Engineering, and of the Graduate School of Business, at Stanford University. I am also a Senior Fellow at the Stanford Institute for Economic Policy Research. My prior teaching positions include: Professor of Economics (1987–1993), Stanford University Economics Department; Professor of Management (1983–1985) and Williams Brothers Professor of Management (1985–1987), Yale University; and Assistant Professor and Professor of Economics (1979–1983), Northwestern University.

7. My work has earned me the following awards and honors:

- John J. Carty Award for the Advancement of Science from the U.S. National Academy of Sciences (2018);
- CME Group-MSRI prize in Innovative Quantitative Applications, Chicago Mercantile Exchange and Mathematical Sciences Research Institute (2017);
- BBVA Foundation Frontiers of Knowledge Prize (2012);

- Nemmers Prize in Economics, Northwestern University (2008);
- Member, National Academy of Sciences (2006);
- Honorary Doctorate, Stockholm School of Economics (2001);
- Fellow, American Academy of Arts and Sciences (1992);
- Fellow, Econometric Society (1984).

8. My *curriculum vitae* is attached as Appendix 1. It lists all of the publications that I have authored during my career, as well as the cases or matters in which I have testified as an expert since 2000.

9. I am being compensated at a rate of \$1400 per hour for my work in this litigation, and was assisted by a team working under my direction and control at Auctionomics. My compensation is not contingent upon my opinions or the outcome in this matter. A list of the materials that I relied upon in the preparation of this report is attached as Appendix 2.

III. Dr. Pirrong Accurately Summarizes the Market Microstructure Literature Regarding the Permanent Price Impact of Potentially Informed Manipulative Trades

10. Dr. Pirrong and Dr. Glosten agree that the market microstructure literature distinguishes between two kinds of price impacts due to individual trades: (i) temporary impacts, which are expected to be quickly reversed; and (ii) permanent impacts, which arise when a trade is made by a trader that other market participants believe *may* have private information about the value of the traded security.

11. **Temporary price impacts:** According to the market microstructure literature, temporary price impacts can arise because market makers try to hold an ideal level of inventory, neither too high nor too low, to perform their role as a counterparty for other traders in a security. If a market maker with an ideal level of inventory buys a security, then after the trade it holds

more inventory than desired, so it lowers its bid and ask prices in an attempt to bring its inventory back toward its ideal level. After a market maker sells, the directional effects are the opposite. According to empirical literature cited in Dr. Pirrong's report, these price adjustments associated with inventory rebalancing are temporary and tend to be reversed within a small number of trades. Dr. Pirrong and Dr. Glosten do not appear to disagree on the subject of temporary price impacts caused by market makers' inventory rebalancing.

12. **Permanent price impacts:** In contrast, trading can also result in permanent price impacts due to *adverse selection*, according to which market participants anticipate the possibility that a trader may have private information to indicate that the price of the security is too low or too high. If a trader who other market participants believe may potentially be privately informed elects to *buy*, then those other market participants are led to *increase* their own estimates of the value of the security and to set *higher* bid and ask prices for the next trades. Similarly, if such a trader elects to *sell*, then other participants will *reduce* their estimates of the value and set *lower* bid and ask prices for the next trades. These revised prices become a new baseline for all future price changes, and the expected value of any further changes are *zero* (see paragraph 15 below).

13. The market microstructure literature terms as "informed" trades those made by traders on the basis of private information relevant to the underlying value of the security.¹ However, other market participants may be uncertain about which trades are based on such information. When there is such uncertainty, these trades are "potentially informed."

¹As Dr. Glosten testified, [REDACTED]

[REDACTED] Glosten Tr. at 95:8–16; 96:14–97:19.

14. Dr. Pirrong and Dr. Glosten appear to agree that the adverse selection effects identified by the Glosten-Milgrom analysis occur not only for informed trades, but for *potentially* informed trades as well.² Even if a particular trade is not actually informed, other market participants, who are unable to discern whether the particular trade is informed or uninformed, would regard that trade as potentially informed. Unless substantially *all* market participants eventually discover that the trade is uninformed, market microstructure theory allows that this uninformed trade could still have a permanent impact.

15. The phrase “permanent price impact” used in Dr. Pirrong’s report and similar phrases used in the market microstructure literature refer to the “martingale property” of transactions prices, as predicted by the Glosten-Milgrom theory. A sequence of prices that has been adjusted to eliminate temporary effects due to inventory rebalancing has the martingale property if the following relationship holds: *conditional on all the publicly available information at the time of any trade, including the price at which the trade takes place, the expected value of the price for the next transaction, and for any future transaction, is equal to the current price.*

16. Dr. Glosten’s report appears to adopt a different interpretation of the phrase “permanent price impact.” He argues that the price impact of any manipulative trade should be expected to be reversed entirely, and so is not “permanent.” He seems to identify the permanent impact of a manipulative trade with the change in the expected value of future transactions prices conditional not only on all public information, but also on the additional, non-public information that the trade is an uninformed, manipulative trade. Including this additional information in the

² Glosten report, ¶¶ 19–20.

expected value computation, Dr. Glosten claims, leads to the conclusion that this impact is zero: none of the price impact of a manipulative trade will be permanent.³

17. To support this conclusion, however, Dr. Glosten implicitly makes two assumptions, neither of which is standard in the market microstructure literature. The first of these is that if market participants could identify manipulative trades, they would regard them as uninformed trades. The second is that soon after any manipulative trade is made, it can be detected by other market participants. As I explain in Section IV.A, Dr. Glosten's arguments for these two premises are speculative and the premises themselves are not supported by the market microstructure literature.

18. If either of the two Glosten assumptions is incorrect, then some manipulative trades would continue to be regarded by other market participants as potentially informed. Such trades would have "permanent" price impacts, even using that term as in Dr. Glosten's report.

19. Although Dr. Glosten's report claims to the contrary that only informed trades can have a permanent price impact, the market microstructure literature does not support that claim: it consistently holds that even *potentially* informed trades can result in a *permanent* price impact. Moreover, if, as Dr. Glosten posits, some other market participants knew with certainty that trades were manipulative and uninformed, and had the incentive to profit on the mispricing, they would trade immediately to preserve the advantage of their private information. Consequently, an observed change in the bid/ask price of the security that persists following the trade would negate Dr. Glosten's premise that other market participants knew that a trade was manipulative and that its reversal was in their interest.

³ Glosten report, ¶ 19.

20. Dr. Glosten further offers four reasons why a manipulative trade must be unwound in ways that would reverse the price impact of the original trade, so that its price impact would be only temporary.⁴ However, these reasons are again insufficient to justify the conclusion of no permanent price impact, and they also are inconsistent with the market microstructure literature, as I explain in Section IV.B.

21. Using the phrase “permanent price impact” as it is used in the market microstructure literature and setting aside Dr. Glosten’s assumptions and claims, which are inconsistent with that literature, Dr. Pirrong is correct in finding that potentially informed trades can have a permanent impact on prices. Because manipulative trades are viewed by market participants as potentially informed, and potentially informed trades can result in permanent price impact, manipulative trades can lead to permanent price impact. Therefore, Dr. Pirrong offers a fair and accurate characterization of the market microstructure theory regarding the permanent price impact of manipulative trades.

IV. Dr. Glosten Fails to Establish His Claim That the Price Impact of Manipulative Trades Is Only Temporary

A. Manipulative Trades Should be Viewed as *Potentially* Informed, Not as “Uninformed”

22. Dr. Glosten’s conclusion—that manipulative trades have no permanent price impact—relies explicitly on his premise that all market participants know “with certainty” that manipulative trades are “uninformed.”⁵ His premise, however, represents a substantial departure from the related market microstructure literature. In much of this literature, market manipulators

⁴ Glosten report, ¶¶ 28–35.

⁵ Dr. Glosten writes: “If market participants *knew with certainty* that a transaction is uninformed, there would be no permanent effect on the price” (Glosten report, ¶ 19, emphasis added). Also: “If the market *knows* that a trade is not based on private information, the expected value of the contract will not change after the trade, that is, uninformed trades will not have a permanent impact on prices” (Glosten report, ¶ 16, emphasis added).

are treated as making some informed and some uninformed trades, with other traders unable to distinguish between the two, leading them to treat these as potentially informed trades. Short excerpts from six such papers along with explanatory comments are presented in a footnote.⁶ Thus, the market microstructure literature is inconsistent with Dr. Glosten's premise that manipulative trades can be readily identified by all market participants.

23. Besides failing to find support in the market microstructure literature, Dr. Glosten's report fails to offer any logical support for the premise that all market participants can readily identify uninformed, manipulative trades. That premise requires—as a matter of timing—either that such trades can: (i) be *immediately* (or even *beforehand*) identified as manipulative and uninformed by market participants; or (ii) be *eventually* identified as

⁶ Allen and Gale (1992) analyze a model in which market participants cannot distinguish an uninformed manipulator from an informed trader: “[i]nvestors do not know whether the entrant is an informed trader or a manipulator.” To this extent, market participants view any entrant as *potentially* informed. See F. Allen and D. Gale, “Stock-Price Manipulation,” *Review of Financial Studies* 5, no. 3 (1992): 509–511.

Aggarwal and Wu (2006) extend the analysis of Allen and Gale (1992) via a similar model in which a manipulator “pools” with an informed trader in equilibrium—that is, other market participants cannot distinguish the manipulator from an informed party. See R. K. Aggarwal and G. Wu, “Stock Market Manipulations,” *Journal of Business* 79, no. 4 (2006): 1937–1938.

Kumar and Seppi (1992), cited by both Dr. Glosten and Dr. Pirrong, proposes to represent the effect of potentially informed manipulations by using a “signal-to-noise ratio,” which measures “the ability of the [market] to predict the manipulator’s futures position and hence to predict and then filter out the manipulator’s uninformative trade...from the spot order flow.” See P. Kumar and D. Seppi, “Futures Manipulation with ‘Cash Settlement’,” *Journal of Finance* 47, no. 4 (1992): 1488–1490.

Jarrow (1994) considers a manipulator whose trades are considered to be *potentially* informed by other market participants. In his analysis, other market participants cannot discern the manipulator’s trades from other informed trades: the price “is *only a function* of the [manipulator’s] holdings in the stock and the derivative security” (emphasis added). This phrase—“*only a function*”—means that the price does *not* depend on whether the trade is manipulative. It is a formulaic way to assert that only the manipulator itself can distinguish its manipulative trades from its informed trades. See R. A. Jarrow, “Derivative Security Markets, Market Manipulation, and Option Pricing Theory,” *The Journal of Financial and Quantitative Analysis* 29, no. 2 (1994): 244–245.

Brunnermeier and Pedersen (2005) finds that “even though traders observe prices, they cannot infer other traders’ actions.” Moreover, they state that “[a]ssuming that the strategic traders can perfectly observe the actions of other strategic traders seems unrealistic.” In the context of their paper, this means that manipulative trades are indistinguishable from normal trades. See M. K. Brunnermeier and L. H. Pedersen, “Predatory Trading,” *The Journal of Finance* 60, no. 4 (2005): 1833.

Finally, Chakraborty and Yilmaz (2004) specifically model “manipulative strategic trading by informed insiders.” Every trade in their analysis is modelled as potentially informed, meaning that market participants do not know which trades are manipulative. See A. Chakraborty and B. Yilmaz, “Informed Manipulation,” *Journal of Economic Theory* 114 (2004): 133.

manipulative and uninformed by market participants.⁷ Dr. Glosten offers no supporting evidence for these possibilities, which defy the logic of financial markets for the reasons described below.

24. First, it is highly improbable that manipulative trades can *immediately* be identified as manipulative and uninformed by market participants. For any agent in the market, the incentive to gather private information—and thus to become an informed trader—is directly related to the volume of its trades and the size of its positions. The Defendants here are among the largest market participants and have powerful incentives to be well-informed. Other participants would likely expect this, and therefore have good reason to treat their trades as potentially informed. This tendency of large traders to be well informed is also observed by others in the market microstructure literature.⁸

25. Second, it is also improbable that the public will *eventually* come to know which trades were manipulative and uninformed. Indeed, Defendants dispute even now which, if any, of the trades were manipulative. Their own arguments therefore refute this hypothesis. The market microstructure literature also contradicts this hypothesis.⁹

26. In sum, in the market microstructure literature, manipulative trades are viewed by other market participants as potentially informed, not “uninformed.” Dr. Glosten’s arguments to the contrary are inconsistent with the market microstructure literature.

⁷ See note 6 above.

⁸ For example, Aggarwal and Wu (2006) conclude that “one way to credibly pose as an informed party is to be an insider. Others such as brokers, underwriters, market makers, or large shareholders can also credibly pose as informed investors.” See R. K. Aggarwal and G. Wu, “Stock Market Manipulations,” *Journal of Business* 79, no. 4 (2006): 1937–1938.

For additional references, see note 6.

⁹ For example, Putnins (2012) identifies as an important problem “incomplete detection (and prosecution) of manipulation.” This recognizes that the public is unlikely to know exactly which trades were manipulative, for otherwise the problem of incomplete detection would be easily resolved. See T. J. Putnins, “Market Manipulation: A Survey,” *Journal of Economic Surveys* 26, no. 5 (2012): 961–962.

B. Potentially Informed Manipulative Trades Result in Permanent Price Impacts

27. Dr. Glosten also argues in his report that, “in every paper cited by Dr. Pirrong, the measured permanent impact is attributed to informed, *not* uninformed (e.g., manipulative), trades.”¹⁰ This, however, is a misstatement of the literature. Instead, the accurate conclusion to draw from the literature is this: permanent price impact can result from *potentially informed* trades as well as from informed trades.

28. According to the market microstructure literature, potentially informed trades lead to permanent price changes because the counterparties anticipate possible adverse selection. Glosten and Milgrom (1985) show that the possibility of adverse selection leads to permanent price changes in the sense described above, namely, that “prices at which transactions actually occur form a martingale.”¹¹ Subsequent authors have expanded on this idea theoretically and tested it empirically, while still concluding that trades viewed by other market participants as potentially informed will impact prices in a permanent way.

(1) For example, taking a theoretical perspective, Easley and O’Hara (1987) expand on the Glosten-Milgrom theory to allow trades to vary in size. In their model, “informed traders prefer to trade larger amounts at any given price. Since uninformed traders do not share this quantity bias, the larger the trade size, the more likely it is that the market maker is trading with an informed trader.” This language highlights that prices are impacted by large trades regardless of whether the trades are actually informed ones. They also show that prices “follow a martingale relative to the set

¹⁰ Glosten report, ¶ 22.

¹¹ L. R. Glosten and P. R. Milgrom, “Bid, Ask, and Transaction Prices in a Specialist Market with Heterogeneously Informed Traders,” *Journal of Financial Economics* 14, no. 1 (1985): 72. *See also* ¶¶ 12–15, above.

of past prices.” They interpret this as meaning that “large blocks have *persistent* price effects” (emphasis in original). See D. Easley and M. O’Hara, “Price, Trade Size, and Information in Securities Markets,” *Journal of Financial Economics* 19, no. 1 (1987): 70, 82–87.¹²

(2) In an empirical study, Huang and Stoll (1997) build and analyze a structural model in which adverse selection generated by potential information leads to permanent price impact. They perform a time-series analysis to distinguish empirically three components of the bid-ask spread: “order processing, adverse information, and inventory holding cost.” They state that “[q]uote adjustments for inventory reasons tend to be reversed over time, while quote adjustments for adverse information are not.” See R. D. Huang and H. R. Stoll, “The Components of the Bid-Ask Spread: A General Approach,” *The Review of Financial Studies* 10, no. 4 (1997): 997.¹³

29. The market microstructure literature distinguishes clearly between price impacts due to adverse selection and price impacts due to inventory effects, rather than between “informed” and “uninformed” trades.¹⁴ Yet, in his report, Dr. Glosten appears to suggest that

¹² See also:

O’Hara (1998) notes that, in models with adverse selection generated by potential information, “[d]epending upon the information the market maker sees, there can be very different price adjustment paths, with some price paths closer to the true value than others. Each path, however, has the property that prices are a [m]artingale.” See M. O’Hara, *Market Microstructure Theory* (Cambridge, MA: Blackwell Publishers, 2005), 65.

¹³ See also:

Easley, Kiefer, O’Hara, and Paperman (1996) “directly measure the effect of informed trading by estimating the market maker’s beliefs” (emphasis in original). They do so by using “the information in trade data to estimate the *probability of informed trade*” (emphasis added). See D. Easley, N. M. Kiefer, M. O’Hara and J. B. Paperman, “Liquidity, Information, and Infrequently Traded Stocks,” *Journal of Finance* 51, no. 4 (1996), 1406–1407.

Vives (2008) states that “[t]here is evidence that market makers do face an adverse selection problem and that spreads reflect asymmetric information,” and that “there is evidence that trades have a permanent impact on prices, pointing toward the effects of private (or public) information.” See X. Vives, *Information and Learning in Markets: The Impact of Market Microstructure* (Princeton, NJ: Princeton University Press 2008), 120.

¹⁴ Recall that adverse selection effects drive permanent price changes, whereas inventory effects drive temporary price changes. See ¶¶ 11–12, above.

adverse selection impacts are generated only by informed trades.¹⁵ His attribution of a similar view to the market microstructure literature is unfounded. In each paper cited in note 12 of the Glosten report, ¶ 22, adverse selection is generated by *potentially* informed trades, not only “informed” trades, as Dr. Glosten appears to suggest.

(1) Quoting from Biais, Glosten, and Spatt (2005), Dr. Glosten highlights that: “[t]his literature has shown that trades have both a transitory and a permanent impact on prices. While the former can be traced back to order-handling and inventory costs, the latter reflects information.” However, “information” as used here refers to the *potential* information that generates adverse selection effects. Biais, Glosten, and Spatt (2005) also clarify that in their paper that adverse selection leads to permanent effects: “Both inventory and adverse-selection theories predict that trades impact prices, but the former predicts that this impact should be transient, while the latter predicts that this impact should be permanent.”¹⁶

(2) Dr. Glosten also cites Hasbrouck (1991) in support of his position, but Hasbrouck explains to the contrary: “trades convey information and therefore cause a persistent impact on the security price.” Furthermore, “[t]he magnitude of the price effect for a given trade size is generally held to be a positive function of *the proportion of potentially informed traders in the population, the probability that such a trader is in fact informed* (i.e., the probability that a private information signal has in fact been observed), *and the precision of the private information*” (emphasis added).¹⁷ The references to the

¹⁵ Glosten report, ¶ 22, note 12.

¹⁶ See B. Biais, L. Glosten, and C. Spatt, “Market Microstructure: A Survey of Microfoundations, Empirical Results, and Policy Implications,” *Journal of Financial Markets* 8 (2005): 220, 232.

¹⁷ J. Hasbrouck, “Measuring the Information Content of Stock Trades,” *Journal of Finance* 46, no. 1 (1991): 179.

“proportion” and “probability” of informed trade are included because participants cannot distinguish informed from uninformed trades, and must respond in the same ways to both.

(3) Dr. Glosten quotes from Stoll (2000): “[i]nformational trading results in permanent price changes” and “[p]rice changes associated with adverse information are permanent adjustments in the equilibrium price.” The reference to adverse selection makes clear that Stoll (2000) uses “information” in the sense of *potential* information just as in the Glosten-Milgrom analysis, in which “[a] supplier of immediacy faces the *danger* that a bid or ask will be accepted by someone with superior- or adverse-information” (emphasis added). Moreover, this leads to permanent price changes: “If the source of the spread is totally informational, the bid-ask bounce, as Glosten and Milgrom (1985) first showed, will not be observed, for in that case the transaction price is a martingale.”¹⁸

(4) Dr. Glosten claims that Fleming, Mizrach, and Nguyen (2017) “conclude that the permanent price impact found in their empirical study is due to information”.¹⁹ He quotes from the study: “More importantly, we show that limit order activities affect prices, and in fact contribute more to the variance of efficient price updates than trades [...] The evidence that limit orders also contain value-relevant information suggests that, contrary to the conventional assumption that traders with better information are liquidity demanders.” However, this quote does not support Dr. Glosten’s claim.

¹⁸ See H. R. Stoll, “Friction,” *Journal of Finance* 55, no. 4 (2000): 1482–1483, 1485, 1492.

¹⁹ Glosten report, ¶ 22, note 12.

(a) The authors use the term “information” to mean *potential* information. They state explicitly that their methodology is “rooted in theoretical microstructure models of information asymmetry. Upon observing a trade, the market maker infers the *probability of trading with an informed trader*, and update prices accordingly” (emphasis added).

(b) Fleming, Mizrach, and Nguyen (2017) further note that this leads to permanence of price impact, in the sense of the martingale condition: “The price revision process thus reflects the information set of the market maker at each price update, which includes the contemporaneous trade, as well as the history of trades and prices.”²⁰

(5) Dr. Glosten quotes from Kraus and Stoll (1972): “The evidence tends to support the liquidity cost version of the distribution hypothesis ... [and this] conclusion is based on a number of pieces of evidence the most important of which is the rapid price recovery of minus tick blocks [i.e., sales] on the day of the block.” However, this does not attribute permanent effects only to informed trades, as Glosten claims in ¶ 22. The logic of Kraus and Stoll (1972) is that because the empirically measured price impact is temporary, the trades considered cannot be based on potential information. As the authors write by way of conclusion: “The purpose of the preceding analyses was to investigate whether the price effects accompanying block trades can be ascribed to a change in the underlying value of the stock (information effect) or to a temporary deviation of prices (distribution effect).” Kraus and Stoll (1972) pre-dates the the

²⁰ See M. J. Fleming, B. Mizrach, and G. Nguyen, “The Microstructure of a U.S. Treasury ECN: The BrokerTec Platform,” *Journal of Financial Markets*, forthcoming (2017): 3, 15–16.

Glosten-Milgrom analysis, and so the authors do not explicitly distinguish between information and potential information.²¹

(6) Dr. Glosten quotes from Huang and Stoll (1996) that their result of permanent price changes on the NYSE are “consistent with the presence of adverse information.” However, as noted above, adverse selection arises from potential information, so this quotation is inconsistent with Dr. Glosten’s position.²²

(7) From Madhavan and Cheng (1997), Dr. Glosten quotes that the authors find that “asymmetric information is a major component of the price impact.” *Asymmetrically informed* traders, however, are the same as *potentially informed* traders: they alone know whether they have relevant private information about the value of the security and what its significance may be. To the extent that market participants cannot distinguish informed trades from uninformed ones, trades are viewed by market participants as potentially informed and result in adverse selection, which drives permanent price changes.²³

(8) Dr. Glosten’s contention about Dr. Pirrong’s use of Glosten and Harris (1988) is simply that the paper “[does] not make any inference between the findings [...] and manipulative trading”.²⁴ Glosten and Harris (1988) does, however, distinguish between the “transitory component” and the “adverse-selection component” of the bid-ask spread. They explain that, as “[i]n the Glosten and Milgrom (1985) model, the adverse-selection spread

²¹ See A. Kraus and H. R. Stoll, “Price Impacts of Block Trading on the New York Stock Exchange,” *Journal of Finance* 27, no. 3 (1972): 587.

²² See R. D. Huang and H. R. Stoll, “Dealer versus Auction Markets: A Paired Comparison of Execution Costs on NASDAQ and the NYSE,” *Journal of Financial Economics* 41, no. 3 (1996): 334.

²³ See A. Madhavan and M. Cheng, “In Search of Liquidity: Block Trades in the Upstairs and Downstairs Markets,” *Review of Financial Studies* 10, no. 1 (1997): 190.

²⁴ Glosten report, ¶ 22, note 12.

component is equal to the revision in market-maker expectations of stock resulting from the submission of an order. When someone submits an order to buy (or sell) stock, the uninformed market-maker, knowing that the order *might* be information-motivated, revises his expectation of the future stock value upward (or downward)” (emphasis added). This supports the argument that *potentially* informed trades result in adverse selection, which leads to permanent price impact. Thus, to the extent that manipulative trades are potentially informed trades, the paper’s findings do apply.²⁵

(9) From Kumar and Seppi (1992), Dr. Glosten notes that one conclusion the paper draws is that there is “price pressure (i.e., subsequently reversed price changes)” following manipulation. Taken in context, this quote addresses the price pressure in the futures market, not in the market for the underlying stock. The futures order flow in that portion of their analysis is known by all market participants to be “completely uninformative about fundamentals,” or the value of the underlying security, and so leads to temporary pressure on the futures price. By contrast, in the same model, both uninformed and informed traders trade in the spot market for the underlying stock. Trades in the spot market are treated as *potentially* informed by market participants, and drive adverse selection.²⁶

30. Despite the literature, Dr. Glosten also takes a different approach to these same issues, offering four reasons that if a trade is manipulative, it might be unwound, thus reversing the price impact and rendering that impact temporary, rather than permanent.²⁷ These reasons all rely on claims that are neither implied nor supported by the market microstructure literature.

²⁵ See L. R. Glosten and L. E. Harris, “Estimating the Components of the Bid/Ask Spread,” *Journal of Financial Economics* 21 (1988): 124.

²⁶ See P. Kumar and D. J. Seppi, “Futures Manipulation with ‘Cash Settlement’,” *Journal of Finance* 47, no. 4 (1992): 1486, 1495.

²⁷ Glosten report, ¶¶ 28–35.

31. First, Dr. Glosten asserts that, after a manipulative trade, the manipulative trader would be left with inventory to rebalance by “unwinding” the manipulation. There is, however, no symmetry in the manipulative trade and its unwinding. A manipulative trader who wants, for example, to raise a price will buy in a way that *maximizes* the price impact. However, when unwinding the trade, that same trader will seek to *minimize* the price impact to avoid losses. Therefore, the upward effect can be expected to exceed the downward effect from unwinding—and that difference may represent a permanent effect.

32. Second, professional traders and others will tend to act on the mistaken pricing. Dr. Glosten posits that these market participants might try to detect manipulative trades. But Dr. Glosten fails to account for the corresponding incentive of manipulative traders to conceal their intent, in order to benefit from their manipulation and unwind their positions to avoid or minimize loss.

33. Third, Dr. Glosten notes that the market participants themselves will have an incentive to take advantage of the mispricing. Like the first reason above, however, Dr. Glosten again ignores trader incentives to minimize price impact while unwinding their position.

34. Fourth, according to Dr. Glosten, other co-conspirators may trade similarly based on their knowledge that the trade was manipulative and that the price level is artificial. But like the second reason, Dr. Glosten’s fourth reason relies on other market participants’ ability to recognize manipulative trades, and their confidence that each trade is uninformed, rather than potentially informed. However, as noted above, both of these assumptions are contrary to the weight of the market microstructure literature.²⁸

²⁸ In particular, see Section IV.A, above.

35. Thus, Dr. Glosten's four reasons that manipulative trades would be unwound in ways that completely reverse their price impacts is unpersuasive as a matter of logic, as well as unsupported by the market microstructure literature. The market microstructure literature demonstrates clearly how potentially informed trades can result in permanent price impact. Therefore, as Dr. Pirrong opines, manipulative trades are likely to have a permanent price impact.

V. Conclusion

36. In summary, Dr. Pirrong accurately interprets the market microstructure literature regarding the permanent price impact of potentially informed trades. To the extent that manipulative trades are viewed by other market participants as potentially informed, they have a permanent price impact. Dr. Glosten's claims to the contrary are not convincing and are not supported by the market microstructure literature.

January 22, 2018

A handwritten signature in blue ink that reads "Paul Milgrom". The signature is written in a cursive style and is positioned above a horizontal line.

Dr. Paul Milgrom

Appendix 1

Paul Robert Milgrom

**Shirley and Leonard Ely, Jr. Professor of Humanities and Sciences
Department of Economics
Stanford University**

579 Serra Mall, Landau Economics Building
Stanford, CA 94305
+1 (650) 723-3397
milgrom@stanford.edu

Education

Ph.D. in Business, Stanford University, January 1979

M.S. in Statistics, Stanford University, April 1978

A.B. in Mathematics with high honors, University of Michigan, May 1970

Employment

2007–present	Senior Fellow, SIEPR, Stanford University
1993–present	Shirley and Leonard Ely, Jr. Professor of Humanities and Sciences, Stanford University
1987–present	Professor of Economics, Stanford University Professor (by courtesy), Graduate School of Business Professor (by courtesy), Department of Management Science and Engineering
1989–91	Director, Stanford Institute for Theoretical Economics
1985–87	Williams Brothers Professor of Management Studies and Professor of Economics, Yale University
1983–85	Professor of Economics and Management, Yale University
1982–83	Visiting Professor, Yale University

- Professor, Department of Managerial Economics and Decision Sciences,
Kellogg Graduate School of Management, Northwestern University
- 1981–82 Associate Professor, Department of Managerial Economics and Decision
Sciences, Kellogg Graduate School of Management, Northwestern
University
- 1979–81 Assistant Professor, Department of Managerial Economics and Decision
Sciences, Kellogg Graduate School of Management, Northwestern
University

Honors, Awards, Prizes, Fellowships, and Grants

- 2018 John J. Carty Award for the Advancement of Science, U.S. National
Academy of Sciences
- 2017 CME Group-MSRI prize in Innovative Quantitative Applications, Chicago
Mercantile Exchange and Mathematical Sciences Research Institute
McKenzie lecture, University of Rochester
Stanford Humanities and Sciences Dean’s Award for Excellence in Graduate
Education
Elected Fellow of the Game Theory Society
Elected Fellow of the Finance Theory Group
- 2016 Nancy Schwartz Memorial Lecture, Northwestern University
- 2015 National Science Foundation Award “Auction Market Design”
Simon’s Institute Public Lecture, University of California, Berkeley
WINE (Web and Internet Economics) Keynote Lecture
- 2014 Golden Goose Award
Keyfitz Lecture, Fields Institute, Toronto
Arrow Lecture, Columbia University
- 2013 Nomura Lecturer, Institute of Mathematics, Oxford University
BBVA Foundation Frontiers of Knowledge Award in Economics, Finance
and Management
- 2012 Elected Vice President of the American Economic Association (term to
begin in 2013)

Inaugural lecture on “Incentive Auctions for Radio Spectrum,” C.V. Starr Center Distinguished Speaker Series, New York University
Oskar Morgenstern lecture on “Designing the US ‘Incentive Auctions’,” Fourth World Congress of the Game Theory Society
Becker Friedman Visitor, University of Chicago
Intertic Stackelberg Lecture on “Auctions for Online Display Advertising”
2011 Eitan Berglas Lecture on “The Applied Science of Market Design,” Tel Aviv University
2010 NSF-SBIR Phase IB Award for “Incorporating Bidder Budget Constraints in Multi-item Auctions”
2009 NSF-SBIR Phase I Award for “Incorporating Bidder Budget Constraints in Multi-Item Auctions”
Nemmers Lecture, Northwestern University
EARIE (European Association for Research in Industrial Organization) Lecture
2008 Erwin Plein Nemmers Prize
W.A. Mackintosh Lecture, Queens University
Simon Newcomb Lecture, Johns Hopkins University
2007 President, Western Economic Association International (WEAI)
National Science Foundation Grant on “Market Design”
2006 Elected to the National Academy of Sciences
Colin Clarke Lecture, Econometric Society Australasian Meeting
Manchot Lecture, University of Bonn
2005 Elected to the Executive Committee of the Econometric Society
Elected Vice President of the Western Economic Association
Chung-Hua Lecturer, Academia Sinica (Taiwan)
Clarendon Lecturer, Oxford University
2004 Fischer-Schulz Lecturer, Econometric Society
Koopmans Lecturer, Yale University
National Science Foundation Research Grant to study “Electronic Auction

Markets”

Council Member, Econometric Society

- 2003 National Science Foundation Research Grant to study “Cumulative Offer Processes”
Landau Economics Teaching Prize, Stanford University
Elected to the Council, Game Theory Society
Distinguished Economist Lecture, Federal Communications Commission
- 2001 Honorary Doctorate, Stockholm School of Economics
- 2000 Taussig Visiting Research Professor, Harvard University
- 1999 Murray S. Johnson Inaugural Lecture, University of Texas
Industry Canada Distinguished Lecture
- 1998 Fain Lecture, Brown University
Lawrence Klein Lecture, University of Pennsylvania
Fellow (2nd time), Center for Advanced Study in the Behavioral Sciences
- 1997 Alberto Bailleres Founder’s Lecture at Instituto Tecnológico Autónomo de México (ITAM)
Plenary Lecturer, Econometric Society Far Eastern Meeting
Plenary Lecturer, Australian Industry Economics Meeting, University of Melbourne
- 1996 Nobel Prize Memorial Lecture (honoring deceased Nobel laureate William Vickrey) at the Royal Swedish Academy of Sciences
- 1995 Churchill Lectures at Cambridge University
Political Economy Special Lecture at Harvard University
- 1994 National Science Foundation Research Grant to study “Comparative Statics, Complementarities, Coordination and Change,” (covering 1994 to 1997)
Woytinsky Distinguished Lecturer, University of Michigan
- 1993 Senior Research Fellow, Institute for Policy Reform
Shirley R. and Leonard W. Ely, Jr. Professor of Humanities and Sciences, Stanford University
- 1992 Fellow, American Academy of Arts and Sciences

- International Guest Scholar, Kyoto University
- 1991 Fellow, Center for Advanced Study in the Behavioral Sciences
National Science Foundation Research Grant to study “Theories of the Firm 2” (covering 1991 to 1994)
- 1990 Center for Economic Policy Research Grant to study “The Economics of Modern Manufacturing”
- 1989 National Science Foundation Grant to direct programs for the Stanford Institute for Theoretical Economics
National Academy of Sciences Award to lecture in China on economics of organizations
- 1988 Olin Distinguished Lecturer, Princeton University
National Science Foundation Research Grant to study “Theories of the Firm” (covering 1988 to 1991)
Center for Economic Policy Research Grant
- 1987 Prize for Best Paper of the Year in the Transactions of the Society of Actuaries
- 1986 Ford Visiting Professor of Economics, University of California, Berkeley
John Simon Guggenheim Fellowship to study “Economic Theories of Organization”
- 1985 Williams Brothers Chair in Management Studies, Yale University
National Science Foundation Research Grant to study “On the Formal Economic Theory of Organizations”
Fellow of the Institute for Advanced Studies, Hebrew University of Jerusalem
Plenary Lecturer at the Fifth World Congress of the Econometric Society
- 1984 Fellow of the Econometric Society
Fellow of Morse College, Yale University
- 1983 Research Award, Actuarial Education and Research Fund
Honorary Master of Arts degree, Yale University
- 1982 National Science Foundation Research Grant to study “The Structure of

- Information in a Productive Organization”
- 1981 IBM Research Chair at Northwestern University
Visiting Research Associate, Stanford University
- 1980 Leonard J. Savage Memorial Thesis Award
National Science Foundation Research Grant to study “Information and Uncertainty in Competitive Bidding”
- 1976 Society of Actuaries Triennial Paper Prize for best paper by an actuary within five of membership, for the period 1973–75
- 1974 Fellow of the Society of Actuaries

Publications

Articles

- “Equilibrium Selection in Auctions and High Stakes Games,” with Joshua Mollner, *Econometrica*, forthcoming
- “Redesigning Spectrum Licenses,” with Anthony Zhang and E. Glen Weyl, *Regulation*, Fall 2017.
- “Economics and Computer Science of a Radio Spectrum Reallocation,” with Kevin Leyton-Brown and Ilya Segal, *Proceedings of the National Academy of Sciences*, July 2017.
- “Adverse Selection and Auction Design in Internet Display Advertising,” with Nick Arnosti and Marissa Beck, *American Economic Review*, October 2016.
- “Ascending Prices and Package Bidding: Further Experimental Analysis,” with John Kagel and Yuanchuan Lien, *Games and Economic Behavior*, May 2014.
- “Designing Random Allocation Mechanisms: Theory and Applications,” with Eric Budish, Yeon-Koo Che and Fuhito Kojima, *American Economic Review*, April 2013.
- “Critical Issues in Market Design,” *Economic Inquiry*, April 2011.
- “Simplified Mechanisms with an Application to Sponsored-Search Auctions,” *Games and Economic Behavior*, September 2010.
- “Ascending Prices and Package Bidding: A Theoretical and Experimental Analysis,” with Yuanchuan Lien and John Kagel, *American Economic Journal: Microeconomics*, August

2010.

“Online Advertising: Heterogeneity and Conflation in Market Design,” with Jon Levin, *American Economic Review*, May 2010.

“Assignment Messages and Exchanges,” *American Economic Journal: Microeconomics*, August 2009. Reprinted in *Handbook of Spectrum Auction Design*, by Martin Bichler and Jacob Goeree (eds.), Cambridge University Press, 2017.

“The Limited Influence of Unemployment on the Wage Bargain,” with Robert Hall, *American Economic Review*, September 2008. Reprinted in *Political Economy: Critical Concepts*, by Norman Schofield, Dino Falaschetti and Andrew Rutten (eds.), New York: Routledge, 2011.

“Substitute Goods, Auctions and Equilibrium,” with Bruno Strulovici, *Journal of Economic Theory*, June 2008

“The Promise of Prediction Markets” (with 22 co-authors), *Science*, May 2008.

“What the Seller Won’t Tell You: Persuasion and Disclosure in Markets,” *Journal of Economics Perspectives*, Spring 2008.

“Core-Selecting Package Auctions,” with Bob Day, *International Journal of Game Theory*, March 2008. Reprinted in *Handbook of Spectrum Auction Design*, by Martin Bichler and Jacob Goeree (eds.), Cambridge University Press, 2017.

“Package Auctions and Package Exchanges” (2004 Fisher-Schultz lecture), *Econometrica*, July 2007.

“Matching with Contracts,” with John Hatfield, *American Economic Review*, September 2005.

“Ascending Auctions with Package Bidding,” with Lawrence M. Ausubel, *Frontiers of Theoretical Economics*, August 2002. Republished in *Advances in Theoretical Economics*, 2002.

“Package Bidding: Vickrey vs Ascending Auctions,” with Lawrence M. Ausubel, *Revue Economique*, May 2002.

“Envelope Theorems for Arbitrary Choice Sets,” with Ilya Segal, *Econometrica*, March 2002.

“Advances in Routing Technologies and Internet Peering Agreements,” with Stan Besen, Bridger Mitchell and Padmanabhan Srinagesh, *American Economic Association Papers and Proceedings*, May 2001.

- “Putting Auction Theory to Work: The Simultaneous Ascending Auction,” *Journal of Political Economy*, April 2000. Reprinted in *Handbook of Spectrum Auction Design*, by Martin Bichler and Jacob Goeree (eds.), Cambridge University Press, 2017.
- “Game Theory and the Spectrum Auctions,” *European Economic Review*, May 1998.
- “Coalition-Proofness and Correlation with Arbitrary Communication Possibilities,” with John Roberts, *Games and Economic Behavior*, November 1996.
- “The LeChatelier Principle,” with John Roberts, *American Economic Review*, March 1996. Reprinted in *Paul Anthony Samuelson, Critical Assessments of Contemporary Economists*, by John Cunningham Wood and Michael McLure (eds.), New York: Routledge, 2004.
- “The Economics of Modern Manufacturing: Technology, Strategy and Organization: Reply,” *American Economic Review*, September 1995.
- “Deterring Predation in Telecommunications: Are Line-of-Business Restraints Needed?” with Susan Gates and John Roberts, *Managerial and Decision Economics*, July 1995. Reprinted in *Deregulating Telecommunications: The Baby Bells’ Case for Competition*, by R.S. Higgins and P.H. Rubin (eds). Chichester: John Wiley & Sons, 1995.
- “Complementarities and Fit: Strategy, Structure and Organizational Change in Manufacturing,” with John Roberts, *Journal of Accounting and Economics*, March 1995.
- “The Firm as an Incentive System,” with Bengt Holmstrom, *American Economic Review*, September 1994. Reprinted in *The Theory of the Firm: Critical Perspectives*, by Nicolai Juul Foss (ed.), New York: Routledge, 2000. Reprinted in *Readings in the Economics of the Division of Labor, Vol 2: Modern Analyses*, by Guang-Zhen Sun (ed.), World Scientific, 2005.
- “Coordination, Commitment and Enforcement: The Case of the Merchant Guild,” with Avner Greif and Barry Weingast, *Journal of Political Economy*, August 1994. Reprinted in *Explaining Social Institutions*, by Jack Knight and Itai Sened (eds.), Ann Arbor: University of Michigan Press, 1995. Reprinted in *Trust*, by Elias Khalil (ed.), London: Edward Elgar Publishing, 2002. Reprinted in *The Foundations Library of the New Institutional Economics*, by Claude Ménard (ed.), London: Edward Elgar Publishing, 2005. Reprinted in *Social Norms, Non-legal Sanctions, and the Law*, by Eric Posner (ed.), London: Edward Elgar Publishing, 2007. Reprinted in *Customary Law*, by Lisa Bernstein and Francesco Parisi (eds.), London: Edward Elgar Publishing, forthcoming.

- “Comparing Equilibria,” with John Roberts, *American Economic Review*, June 1994. Reprinted in *Equilibrium*, by Donald Walker (ed.), Edward Elgar Publishing, 2000.
- “Comparing Optima: Do Simplifying Assumptions Affect Conclusions?” *Journal of Political Economy*, June 1994.
- “Complementarities and Systems: Understanding Japanese Economic Organization,” with John Roberts, *Estudios Economicos*, April 1994.
- “Monotone Comparative Statics,” with Chris Shannon, *Econometrica*, January 1994.
- “Organizational Prospects, Influence Costs and Ownership Changes,” with Margaret Meyer and John Roberts, *Journal of Economics and Management Strategy*, Spring 1992.
- “Pay, Perks and Parachutes: Do They Pay?” with John Roberts, *Stanford Business*, 1992.
- “Information and Timing in Repeated Partnerships,” with Dilip Abreu and David Pearce, *Econometrica*, November 1991.
- “A Theory of Hierarchies Based on Limited Managerial Attention,” with John Geanakoplos, *Journal of Japanese and International Economies*, September 1991. Reprinted in *The Economics of Organization and Bureaucracy*, by Peter Jackson (ed.), London: Edward Elgar Publishing, 2013.
- “Complementarities, Momentum, and the Evolution of Modern Manufacturing,” with Yingyi Qian and John Roberts, *American Economic Association Papers and Proceedings*, May 1991.
- “Multitask Principal-Agent Analyses: Incentive Contracts, Asset Ownership and Job Design,” with Bengt Holmstrom, *Journal of Law, Economics and Organization*, Spring 1991. Reprinted in *Transaction Cost Economics*, by Oliver Williamson and Scott Masten (eds.), London: Edward Elgar Publishing, 1994. Reprinted in *The Principal-Agent Model: The Economic Theory of Incentives*, by J-J Laffont (ed.), Cheltenham: Edward Elgar Press, 2003. Reprinted in *The International Library of the New Institutional Economics*, by Claude Ménard (ed.), London: Edward Elgar Publishing, 2005. Reprinted in *The Economic Nature of the Firm*, by Louis Putterman and Randall Kroszner (ed.), Cambridge University Press, 1996. Reprinted in *The Economics of Contracts*, by Patrick Bolton, Barbara and David Zalaznick (eds.), Cheltenham: Edward Elgar Press, 2008. Reprinted in *Institutional Law and Economics*, by Pablo Spiller (ed.), Cheltenham: Edward Elgar Press, forthcoming.
- “Adaptive and Sophisticated Learning in Repeated Normal Form Games,” with John Roberts,

Games and Economic Behavior, February 1991. Reprinted in *Recent Developments in Game Theory*, by E. Maskin (ed.), Cheltenham: Edward Elgar, 1998.

“Rationalizability, Learning and Equilibrium in Games with Strategic Complementarities,” with John Roberts, *Econometrica*, November 1990. Reprinted in *Recent Developments in Game Theory*, by E. Maskin (ed.), Cheltenham: Edward Elgar, 1998.

“The Economics of Modern Manufacturing: Technology, Strategy and Organization,” with John Roberts, *American Economic Review*, June 1990. Reprinted in *Vestnik St. Petersburgskogo Universiteta, Economics Seria* (the Journal of the Economics Faculty of St. Petersburg University), 1993 (in translation). Reprinted in *Economics of the Firm: Lessons in Business Organization*, by Andrei Demin and Valery Katkalo (eds.), St. Petersburg, Russia: 1994. Reprinted in *The Economics of Communications and Information*, by Donald Lamberton (ed.), Cheltenham: Edgar Elgar Publishing, 1996. Reprinted in *Readings in Applied Microeconomic Theory: Market Forces and Solutions*, by Robert E. Kuenne (ed.), Blackwell Publishers, 2000. Reprinted in *Fundamentals of Business Strategy*, by Mie Augur and David Teece (eds.), Sage Publications, 2007.

“Short Term Contracts and Long Term Agency Relationships,” with Drew Fudenberg and Bengt Holmstrom, *Journal of Economic Theory*, June 1990.

“The Efficiency of Equity in Organizational Decision Processes,” with John Roberts, *American Economic Review Papers and Proceedings*, May 1990.

“The Role of Institutions in the Revival of Trade: The Medieval Law Merchant,” with Douglass North and Barry Weingast, *Economics and Politics*, March 1990. Reprinted in *Trade in the Pre-Modern Period: 1400-1700*, by Douglas Irwin (ed.), London: Edward Elgar Publishing, 1996. Reprinted in *Reputation: Studies in the Voluntary Elicitation of Good Conduct*, by Daniel B. Klein (ed.), Ann Arbor, University of Michigan Press, 1997. Reprinted in *The Political Economy of Institutions*, by Claude Ménard (ed.), London: Edward Elgar Publishing, 2004. Reprinted in *International Institutions in the New Global Economy*, by Lisa L. Martin (ed.), London: Edward Elgar Publishing, 2005. Reprinted in *Anarchy and the Law*, by Edward Stringham (ed.), New Brunswick, New Jersey: Transaction Publishers, 2006. Reprinted in *Social Norms, Non-Legal Sanctions, and the Law*, by Eric A. Posner (ed.), London: Edward Elgar Publishing, 2007.

“Regulating Trade Among Agents,” with Bengt Holmstrom, *Journal of Institutional and Theoretical Economics*, March 1990. Reprinted in *The New Institutional Economics*, by Erik G. Furubotn and Rudolph Richter (eds.), College Station: Texas A&M University

Press, 1991.

“Auctions and Bidding: A Primer,” *Journal of Economic Perspectives*, Summer 1989. Reprinted in *Readings in Microeconomic Theory*, by Manfredi La Manna (ed.), London: Dryden Press, 1997.

“Communication and Inventories as Substitutes in Organizing Production,” with John Roberts, *Scandinavian Journal of Economics*, September 1988.

“Economic Theories of Organization: Past, Present and Future,” with John Roberts, *Canadian Journal of Economics*, August 1988. Reprinted in *The Economics of Contracts and Industrial Organization: A Reader*, Peter Buckley and Jonathan Michie (eds.), Oxford University Press, 1996.

“An Economic Approach to Influence Activities and Organizational Responses,” with John Roberts, *American Journal of Sociology*, July 1988.

“Employment Contracts, Influence Activities and Efficient Organization Design,” *Journal of Political Economy*, February 1988.

“Job Discrimination, Market Forces, and the Invisibility Hypothesis,” with Sharon Oster, *Quarterly Journal of Economics*, August 1987. Reprinted in *Learning in Labour Markets*, by Michael Waldman (ed.), Cheltenham: Edward Elgar Press.

“Informational Asymmetries, Strategic Behavior and Industrial Organization,” with John Roberts, *American Economic Association Papers and Proceedings*, May 1987.

“Aggregation and Linearity in the Provision of Intertemporal Incentives,” with Bengt Holmstrom, *Econometrica*, March 1987. Reprinted in *The Principal-Agent Model: The Economic Theory of Incentives*, by J-J Laffont (ed.), Cheltenham: Edward Elgar Press. Reprinted in *The Economics of Contracts*, by Patrick Bolton, Barbara and David Zalaznick (eds.), Cheltenham: Edward Elgar Press.

“Price and Advertising Signals of Product Quality,” with John Roberts, *Journal of Political Economy*, August 1986. Reprinted in *Antitrust and Competition*, by Andrew Kleit (ed.), Cheltenham: Edward Elgar Publishing, 2005. Reprinted in *The Economics of Marketing*, Martin Carter, by Mark Casson and Vivek Suneja (eds.), Cheltenham: Edgar Elgar Publishing, 1998. Reprinted in *Readings in Industrial Organization*, by Luis M.B. Cabral (ed.), Oxford: Blackwell Publishers, 2000.

“Relying on the Information of Interested Parties,” with John Roberts, *Rand Journal of Economics*, April 1986. Reprinted in *Economics of Evidence, Procedure and Litigation*,

by Chris William Sanchirico (ed.), Cheltenham: Edward Elgar Publishing, 2007.

“Distributional Strategies for Games with Incomplete Information,” with Robert Weber, *Mathematics of Operations Research*, November 1985.

“Bid, Ask and Transactions Prices in a Specialist Market with Heterogeneously Informed Traders,” with Lawrence R. Glosten, *Journal of Financial Economics*, March 1985.

“Reply to the Comments on ‘Measuring the Interest Rate Risk’,” *Transactions of the Society of Actuaries*, XXXVII, 1985

“Measuring the Interest-Rate Risk,” *Transactions of the Society of Actuaries*, XXXVII, 1985.

“Competitive Bidding with Proprietary Information,” with Richard Engelbrecht-Wiggans and Robert Weber, *Journal of Mathematical Economics*, April 1983.

“A Theory of Auctions and Competitive Bidding,” with Robert Weber, *Econometrica*, September 1982. Reprinted in *Game Theory in Economics*, by Ariel Rubinstein (ed.), London: Edward Elgar Publishing, 1990. Reprinted in *The Economics of Information*, by Steven A. Lippman and John E. Anderson (eds.), London: Edward Elgar Publishing, 1994. Reprinted in *The Economic Theory of Auctions*, by Paul Klemperer (ed.), London: Edward Elgar Publishing, 1999. Reprinted in *Readings in Applied Microeconomic Theory: Market Forces and Solutions*, by Robert E. Kuenne (ed.), Blackwell Publishers, 2000.

“Predation, Reputation, and Entry Deterrence,” with John Roberts, *Journal of Economic Theory*, August 1982. Reprinted in *Antitrust and Competition*, by Andrew Kleit (ed.), Cheltenham: Edward Elgar Publishing, 2005. Reprinted in *The Economics of Reputation*, by Jill J. McCluskey and Jason Winfree (eds.), Edward Elgar Publishing, 2017.

“Rational Cooperation in the Finitely-Repeated Prisoners’ Dilemma,” with David Kreps, John Roberts and Robert Wilson, *Journal of Economic Theory*, August 1982. Reprinted in *Game Theory in Economics*, by Ariel Rubinstein (ed.), Cheltenham: Edward Elgar Publishing, 1990. Reprinted in *Trust*, by Elias L. Khalil (ed.), Cheltenham: Edward Elgar Publishing, 2003.

“The Value of Information in a Sealed Bid Auction,” with Robert Weber, *Journal of Mathematical Economics*, June 1982. Reprinted in *The Economic Theory of Auctions*, by Paul Klemperer (ed.), London: Edward Elgar Publishing, 1999.

“Limit Pricing and Entry Under Incomplete Information: An Equilibrium Analysis,” with John

Roberts, *Econometrica*, March 1982. Reprinted in *Industrial Organization*, by Oliver Williamson (ed.), London: Edward Elgar Publishing, 1990. Reprinted in *The Economics of Information*, by Steven A. Lippman and John E. Anderson (eds.), London: Edward Elgar Publishing, 1994. Reprinted in *Readings in Industrial Organization*, edited by Luis M.B. Cabral (ed.), Oxford: Blackwell Publishers, 2000. Reprinted in *Pricing*, by Michael Waldman and Justin P. Johnson (ed.), London: Edward Elgar Publishing, 2007.

“Information, Trade and Common Knowledge,” with Nancy Stokey, *Journal of Economic Theory*, February 1982.

“Good News and Bad News: Representation Theorems and Applications,” *Bell Journal of Economics*, October 1981.

“Rational Expectations, Information Acquisition, and Competitive Bidding,” *Econometrica*, July 1981. Reprinted in *The Economic Theory of Auctions*, by Paul Klemperer (ed.), London: Edward Elgar Publishing, 1999.

“An Axiomatic Characterization of Common Knowledge,” *Econometrica*, January 1981.

“A Convergence Theorem for Competitive Bidding with Differential Information,” *Econometrica*, May 1979.

“On Understanding the Effects of GAAP Reserve Assumptions,” *Transactions of the Society of Actuaries*, XXVII, 1975.

Books

Discovering Prices: Auction Design in Markets with Complex Constraints. Columbia University Press, 2017.

Putting Auction Theory to Work. Cambridge: Cambridge University Press, 2004.

Contributions to Books and Proceedings

“Winning Play in Spectrum Auctions,” with Jeremy Bulow and Jonathan Levin, in *Handbook of Spectrum Auction Design*, by Martin Bichler and Jacob Goeree (eds.), Cambridge University Press, 2017.

“Designing the US Incentive Auction,” in *Handbook of Spectrum Auction Design*, by Martin Bichler and Jacob Goeree (eds.), Cambridge University Press, 2017.

“Optimal Incentives in Core-Selecting Auctions,” with Bob Day, in *The Handbook of Market*

Design, by Zvika Neeman, Al Roth, and Nir Vulkan (eds.), Oxford University Press, 2013.

“Incentive Auction: Rules and Discussion,” with Lawrence Ausubel, Jonathan Levin and Ilya Segal, published as Appendix C of the FCC 12-118 (Notice of Proposed Rulemaking on the Incentive Auction, Released October 2, 2012).

“Complementarity in Organizations,” with Erik Brynjolfsson, in *The Handbook of Organizational Economics*, by John Roberts and Bob Gibbons (eds.), Princeton University Press, 2012.

“Multipliers and the LeChatelier Principle,” in *Samuelsonian Economics and the Twenty-First Century*, by Michael Szenberg, Lall Ramrattan and Aron Gottesman (eds.), Oxford University Press, 2006.

“The Clock-Proxy Auction: A Practical Combinatorial Design,” with Lawrence M. Ausubel and Peter Cramton, in *Combinatorial Auctions*, by Peter Cramton, Richard Steinberg and Yoav Shoham (eds.), MIT Press, 2005. Reprinted in *Handbook of Spectrum Auction Design*, by Martin Bichler and Jacob Goeree (eds.), Cambridge University Press, 2017.

“Ascending Proxy Auctions,” with Lawrence M. Ausubel, in *Combinatorial Auctions*, by Peter Cramton, Richard Steinberg and Yoav Shoham (eds.), MIT Press, 2005.

“The Lovely but Lonely Vickrey Auction,” with Lawrence M. Ausubel, in *Combinatorial Auctions*, by Peter Cramton, Richard Steinberg and Yoav Shoham (eds.), MIT Press, 2005.

“Competitive Effects of Internet Peering Policies,” with Bridger Mitchell and Padmanabhan Srinagesh, in *The Internet Upheaval*, by Ingo Vogelsang and Benjamin Compaine (eds.), Cambridge: MIT Press, 2000.

“A Theory of Auctions and Competitive Bidding, II,” with Robert Weber, in *The Economic Theory of Auctions*, by Paul Klemperer (ed.), Edward Elgar Publishing, 1999.

“Combination Bidding in Spectrum Auctions,” in *Competition, Regulation and Convergence: Current Trends in Telecommunications Research*, by Sharon Gillett and Ingo Vogelsang (eds.), New Jersey: Lawrence Erlbaum Associates, Publishers, 1999.

“The Internal Politics of the Firm,” with John Roberts, in *The Politics of Exchange and the Economics of Power*, by Samuel Bowles, Maurizio Franzini and Ugo Pagano (eds.), New York: Routledge, 1998.

“Procuring Universal Service: Putting Auction Theory to Work,” in *Le Prix Nobel: The Nobel*

Prizes, 1996, Nobel Foundation, 1997.

“Procuring Universal Telephone Service,” in *1997 Industry Economics Conference, Industry Commission (ed.)*, *Conference Proceedings*, 1997, AGPS.

“Complementarities in the Transition from Socialism: A Firm-Level Analysis,” with Susan Gates and John Roberts, in *Reforming Asian Socialism: The Growth of Market Institutions*, by John McMillan and Barry Naughton (eds.), Ann Arbor: University of Michigan Press, 1996.

“Continuous Adjustment and Fundamental Change in Business Strategy and Organization,” with John Roberts, in *Trends in Business Organization: Do Participation and Cooperation Increase Competitiveness?*, by Horst Siebert (ed.), Tübingen: J.C.B. Mohr (Paul Siebeck), 1995.

“Johnson Controls, Inc—Automotive Systems Group: The Georgetown Kentucky Plant,” with John Roberts, *Case #S-BE-9, Stanford Graduate School of Business*, November 1993.

“Is Sympathy an Economic Value? Philosophy, Economics and the Contingent Valuation Method,” in *Contingent Valuation: A Critical Assessment*, by Jerry Hausman (ed.), Elsevier-North Holland, 1993.

“The Real Output of the Stock Exchange,” with Timothy F. Bresnahan and Jonathan Paul, in *Output Measurement in the Services Sectors*, by Zvi Griliches (ed.), 1992.

“Bargaining Costs, Influence Costs and the Organization of Economic Activity,” with John Roberts, in *Perspectives on Positive Political Economy*, by James E. Alt and Kenneth A. Shepsle (eds.), Cambridge: Cambridge University Press, 1990. Reprinted in *Transaction Cost Economics*, by Oliver Williamson and Scott Masten (eds.), London: Edward Elgar Publishing Co., 1994. Reprinted in *The International Library of the New Institutional Economics*, by Claude Ménard (ed.), London: Edward Elgar Publishing, 2003. Reprinted in *The Economic Nature of the Firm*, by Louis Putterman and Randall Kroszner (eds.), Cambridge University Press, 1996. Reprinted in *The International Library of the New Institutional Economics*, by Claude Ménard (ed.), London: Edward Elgar Publishing, 2005.

“New Theories of Predatory Pricing,” with John Roberts, *Industrial Structure in the New Industrial Economics*, by Giacomo Bonanno and Dario Brandolini (eds.), Oxford: Oxford University Press, 1990.

“An Essay on Price Discrimination,” in *The Economics of Imperfect Competition and Employment: Joan Robinson and Beyond*, by George Feiwel (ed.), New York:

MacMillan and New York: New York University Press, 1989.

“Predatory Pricing,” in *The New Palgrave: A Dictionary of Economic Theory and Doctrine*, by J. Eatwell, M. Milgate, and P. Newman (eds.), London: MacMillan Press Ltd., 1988.

“Auction Theory,” in *Advances in Economic Theory: Fifth World Congress*, by Truman Bewley (ed.), London: Cambridge University Press, 1987.

“The Economics of Competitive Bidding: A Selective Survey,” in *Social Goals and Social Organization: A Volume in Honor of Elisha Pazner*, by L. Hurwicz, D. Schmeidler and H. Sonnenschein (eds.), London: Cambridge University Press, 1985.

“Private Information in an Auction-Like Securities Market,” in *Auctions, Bidding and Contracting: Uses and Theory*, by R. Engelbrecht-Wiggans, M. Shubik and R. Stark (eds.), New York: New York University Press, New York, 1983.

“Topologies on Information and Strategies in Normal-Form Games with Incomplete Information,” with Robert Weber, in *Game Theory and Mathematical Economics*, by O. Moeschlin and D. Pallaschke (eds.), New York: North Holland, 1981.

Others

“The Case for Unlicensed Spectrum,” with Jonathan Levin, October 2011.

“Making Carbon Markets Work,” SIEPR, May 2009.

“Using Procurement Auctions to Allocate Broadband Stimulus Grants,” SIEPR, May 2009.

“The Promise of Prediction Markets,” with multiple co-authors, May 2008.

“Economists’ Statement on US Broadband Policy,” with multiple co-authors, March 2006.

“Promoting Efficient Use of Spectrum Through Elimination of Barriers to Secondary Markets,” with multiple co-authors, February 2001.

“An Economist’s Vision of the B-to-B Marketplace,” Palo Alto: Perfect, 2000.

Selected Working Papers

“AI and Market Design,” with Steve Tadelis, January 2018.

“Deferred Acceptance Auctions and Radio Spectrum Reallocation,” with Ilya Segal, September 2017.

“When Should Control Be Shared?” with Eva Meyersson Milgrom and Ravi Singh, April 2007.

Major Professional Activities and Affiliations

2016–17	National Academy of Sciences: Class Membership Committee Chair, NAS Temporary Nominating Group
2016	National Academy of Sciences: Air Force Studies Board Committee
2015–present	Editorial Board, Proceedings of the National Academy of Sciences Executive Supervisory Committee, CERGE-EI National Academies’ Intelligence Science and Technology Experts Group (ISTEG)
2012–17	Lead consultant to Federal Communications Commission Incentive Auctions Task Force
2012–14	Editorial Board of European Journal of Pure and Applied Mathematics
2009–present	Editorial Board of AEJ-Microeconomics
2007–08	President, Western Economic Association International (WEAI)
2006–07	Member, National Academy of Sciences President-Elect, Western Economic Association International (WEAI)
2005–06	Vice President, Western Economic Association International (WEAI)
2005–08	Executive Committee of the Econometric Society
2004–06	Council, Econometric Society
2003–present	Council, Game Theory Society
2000–02	Chief economist, Perfect Commerce
1997–02	Editorial Consultant, MIT Press
1997–99	Editorial Board, Journal of Comparative Economics
1996–16	Founder and Director, Market Design Inc. (Chairman, 1996–02)
1996	Nemmers Prize Selection Committee, Northwestern University
1996–06	Advisory Board, Microeconomics Abstracts

1995–05	Advisory Board, Economics Research Network
1994–95	Program Committee, 1995 World Congress of the Econometric Society
1993–95	Senior Research Fellow, Institute for Policy Reform
1993–00	Associate Editor, American Economic Review
1992–present	Fellow, American Academy of Arts and Sciences
1990–93	Co-Editor, American Economic Review
1990–present	Associate Editor, Games and Economic Behavior
1989–92	Associate Editor, Journal of Financial Intermediation
1987–90	Associate Editor, Econometrica
1985–89	Associate Editor, Rand Journal of Economics
1983–87	Associate Editor, Journal of Economic Theory
1984	Chair, Program Committee, Econometric Society Winter Meetings
1984–present	Fellow, Econometric Society
1980–present	Member, American Economic Association

Appendix 2

Materials Relied Upon

Academic Papers

Aggarwal, Rajesh K., and Guojun Wu. “Stock Market Manipulations.” *Journal of Business* 79, no. 4 (2006): 1915–1953.

Allen, Franklin, and Douglas Gale. “Stock-Price Manipulation.” *Review of Financial Studies* 5, no. 3 (1992): 503–529.

Biais, Bruno, Larry Glosten, and Chester Spatt. “Market Microstructure: A Survey of Microfoundations, Empirical Results, and Policy Implications.” *Journal of Financial Markets* 8, no. 2 (2005): 217–264.

Brunnermeier, Markus K., and Lasse Heje Pedersen. “Market Liquidity and Funding Liquidity.” *Review of Financial Studies* 22, no. 6 (2008): 2201–2238.

Chakraborty, Archishman, and Bilge Yilmaz. “Informed Manipulation.” *Journal of Economic Theory* 114, no. 1 (2004): 132–152.

Easley, David, Nicholas M. Kiefer, Maureen O’Hara, and Joseph B. Paperman. “Liquidity, Information, and Infrequently Traded Stocks.” *Journal of Finance* 51, no. 4 (1996): 1405–1436.

Easley, David, and Maureen O’Hara. “Price, Trade Size, and Information in Securities Markets.” *Journal of Financial Economics* 19, no. 1 (1987): 69–90.

Fleming, Michael J., Bruce Mizrach, and Giang Nguyen, “The Microstructure of a U.S. Treasury ECN: The BrokerTecPlatform.” *Journal of Financial Markets*, forthcoming (2017).

Glosten, Lawrence R., and Lawrence E. Harris. “Estimating the Components of the Bid/Ask Spread.” *Journal of Financial Economics* 21 (1988): 123–142.

Glosten, Lawrence R., and Paul R. Milgrom. “Bid, Ask and Transaction Prices in a Specialist Market with Heterogeneously Informed Traders.” *Journal of Financial Economics* 14, no. 1 (1985): 71–100.

Hasbrouck, Joel. "Measuring the Information Content of Stock Trades." *Journal of Finance* 46, no. 1 (1991): 179–207.

Huang, Roger D., and Hans R. Stoll. "Dealer Versus Auction Markets: A Paired Comparison of Execution Costs on NASDAQ and the NYSE." *Journal of Financial Economics* 41, no. 3 (1996): 313–357.

Huang, Roger D., and Hans R. Stoll. "The Components of the Bid-Ask Spread: A General Approach." *Review of Financial Studies* 10, no. 4 (1997): 995–1034.

Jarrow, Robert A. "Derivative Security Markets, Market Manipulation, and Option Pricing Theory." *Journal of Financial and Quantitative Analysis* 29, no. 2 (1994): 241–261.

Kraus, Alan, and Hans R. Stoll. "Price Impacts of Block Trading on the New York Stock Exchange," *Journal of Finance* 27, no. 3 (1972): 569–588.

Kumar, Praveen, and Duane J. Seppi. "Futures Manipulation with 'Cash Settlement'." *Journal of Finance* 47, no. 4 (1992): 1485–1502.

Madhavan, Ananth, and Minder Cheng. "In Search of Liquidity: Block Trades in the Upstairs and Downstairs Markets." *Review of Financial Studies* 10, no. 1 (1997): 175–203.

Pirrong, Craig. "The Economics of Commodity Market Manipulation: A Survey." *Journal of Commodity Markets* 5, no. 1 (2017): 1–17.

Putnins, Talis J. "Market Manipulation: A Survey." *Journal of Economic Surveys* 26, no. 5 (2012): 952–967.

Stoll, Hans R. "Friction." *Journal of Finance* 55, no. 4 (2000): 1479–1514.

Books

Hasbrouck, Joel. *Empirical Market Microstructure: The Institutions, Economics, and Econometrics of Securities Trading*. Oxford: Oxford University Press, 2007.

O'Hara, Maureen. *Market Microstructure Theory*. Cambridge, MA: Blackwell, 1995.

Vives, Xavier. *Information and Learning in Markets: The Impact of Market Microstructure*. Princeton, NJ: Princeton University Press, 2010.